[redacted]

Copy No. 113
RM No. L8B13

[redacted]

NACA

RESEARCH MEMORANDUM

MEASUREMENT THROUGH THE SPEED OF SOUND OF STATIC PRESSURES ON THE REAR OF UNSWEPT AND SWEPTBACK CIRCULAR CYLINDERS AND ON THE REAR AND SIDES OF A WEDGE BY THE NACA WING-FLOW METHOD

By

Richard H. Sawyer and Fred L. Daum

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

July 21, 1948

[redacted]

Classification cancelled (or changed to Unclassified

By Authority of NASA Tech. Pub. Announcement 57 29 Jan 64
(OFFICER AUTHORIZED TO CHANGE)

By

NK
GRADE OF OFFICER MAKING CHANGE)

11 Apr 61
DATE

 [redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

MEASUREMENT THROUGH THE SPEED OF SOUND OF STATIC PRESSURES ON THE REAR OF UNSWEPT AND SWEPTBACK CIRCULAR CYLINDERS AND ON THE REAR AND SIDES OF A WEDGE BY THE NACA WING-FLOW METHOD

By Richard H. Sawyer and Fred L. Daum

SUMMARY

Static-pressure measurements were made through the speed of sound by the NACA wing-flow method at the rear of two unswept circular cylinders of different length-diameter ratio, and one 45° sweptback circular cylinder. Additional measurements were made at the rear and sides of a wedge. A Mach number range from about 0.7 to about 1.2 was covered in the tests.

The results of the tests indicated that the static pressures at the rear of the unswept cylinders and wedge decreased considerably with increase in Mach number from 0.70 to 1.0. Comparison of the results for the unswept cylinders of different length-diameter ratio showed that the decrease in static pressure began at a lower Mach number and was of greater magnitude for the cylinder of higher length-diameter ratio. For the sweptback cylinder, the rapid pressure decrease was delayed to increasingly higher Mach numbers with increase in distance from the root. The static pressures on the sides of the wedge increased considerably with increase in Mach number from 0.90 to 1.17.

INTRODUCTION

In connection with the pressure survey of the test region in the development of the NACA wing-flow technique for transonic research, reference 1, static-pressure measurements were made at several spanwise locations at the rear of two unswept circular cylinders and one sweptback circular cylinder and at the base of a wedge at Mach numbers extending through the speed of sound. Pressure measurements were also made at one spanwise station at midchord on each face of the wedge.

These data, although limited in scope and application, are believed to be of considerable interest in indicating some of the basic effects of the changes in flow characteristics in the transonic speed range.

[redacted]

APPARATUS AND TESTS

The cylinders used for the tests were made of $\frac{3}{8}$-inch-diameter steel tubing. Two of the cylinders, 10 inches and 14 inches long, were mounted normal to the wing surface at 45 percent chord on the modified ammunition-compartment door of a P-51D airplane (fig. 1). The third cylinder, 14 inches long, was mounted at 45° from the normal to the wing surface at 42.5 percent chord, (fig. 2). The outboard end of each of the cylinders was closed with a hemispherical fitting.

The wedge had a chord of 2.5 inches, a span of 10 inches, and an included angle of 8°. The wedge was mounted with its spanwise axis normal to the wing surface at 45 percent chord and was free to aline itself with the local air flow (fig. 3). A circular end plate was fixed to the end of the wedge adjacent to the wing surface.

Pressure measurements were made by means of orifices in the rear of the cylinders and on the rear and sides of the wedge connected to NACA recording manometers. The location of the orifices above the wing surface is indicated in the sketches of figure 4. Reference static pressures and the Mach number, or, in effect, the free-stream conditions of the tests, were determined by static-pressure surveys of the test region in separate tests without a model in place. The chordwise variation of the reference static pressure close to the wing surface was determined from pressure measurements with static-pressure orifices flush with the wing surface (similar to the manner described in reference 1). The variation of the reference static pressures normal to the wing surface was determined from pressure measurements with a static-pressure tube mounted at various heights above the wing surface. The tests were made in high-speed dives of the P-51D airplane such that Mach numbers at the test station on the wing ranged from about 0.7 to 1.2. The corresponding Reynolds numbers ranged from about 6×10^4 to 10×10^4 for the unswept cylinders, from about 9×10^4 to 14×10^4 for the sweptback cylinder, and from about 4×10^5 to 7×10^5 for the wedge.

The measurement of the pressures and the Mach number from a consideration of the sensitivity of the measuring instruments is estimated to be within the following limits:

Pressure, inches of water	± 0.2
Mach number	± 0.005

RESULTS AND DISCUSSION

The results of the tests are presented in figure 4 as a plot of the static-pressure ratio p/p_o against M, where p is the static pressure measured at the orifice in the model and p_o and M are the effective free-stream static pressure and Mach number, respectively, at the orifice location.

The static pressures on the rear of the 10-inch and 14-inch unswept cylinders and on the base of the wedge (figs. 4(a) to 4(c)) seem to show no consistent variation of pressure with spanwise position of the orifice. For these models, the variation of pressure with Mach number was approximately the same for all of the orifices of a given model. In general, a decrease in pressure of from 25 to 40 percent of free-stream static pressure occurred with increase in Mach number from 0.7 to 1.0 for all three models.

For the 10-inch unswept cylinder (fig. 4(a)), the variation of pressure with Mach number was fairly constant up to a Mach number of about 0.95, decreased rapidly with further increase in Mach number to 1.0, and then remained approximately constant with further increase in Mach number. The variation of pressure with Mach number for the 14-inch unswept cylinder (fig. 4(b)) was similar to that for the 10-inch unswept cylinder except that the rapid decrease of pressure occurred at about 0.025 lower Mach number; at Mach numbers above 0.95, the pressure reached a somewhat lower constant value than for the shorter cylinder. These results indicate an adverse effect of increased length-diameter ratio (or aspect ratio) at high subsonic Mach numbers which is in agreement with previous results on the effect of aspect ratio of airfoils at high subsonic Mach numbers (reference 2).

For comparison with the results obtained on the unswept cylinders, the static pressure measured at a Reynolds number of 22,000 on the rear of a circular cylinder (two-dimensional) in the wind-tunnel tests of reference 3, is plotted on figures 4(a) and 4(b) at a Mach number of 0.695. The agreement is reasonably good. Although the Reynolds number of the wind-tunnel tests was approximately one-third that of the present tests, it appears, according to results obtained by Ferri (reference 4), that Reynolds number effects on the pressure distribution around cylinders is negligible at Mach numbers above about 0.70.

The base pressures on the wedge (fig. 4(c)) showed a more gradual decrease with Mach number than the pressures on the rear of the unswept cylinders up to a Mach number of 1.0 and then became nearly constant at the higher Mach numbers. The pressures were considerably higher on the base of the wedge than on the rear of the unswept cylinders at all Mach numbers.

Rotating the 14-inch cylinder back 45° (fig. 4(d)) caused a marked difference in the variation of the pressure with Mach number at the three orifice positions. Up to a Mach number of 0.85, the pressures at the three orifice positions (about 4, 25, and 54 percent of the length of the cylinder from the root) were practically the same. With further increase in Mach number the inboard orifice showed a pressure decrease generally similar to that of the unswept cylinder, but with increasing distance from the root, the pressure decrease was delayed to increasingly higher Mach numbers; for the outermost orifice (54 percent) the pressure decrease did not occur until a Mach number of 1.07 was attained, a Mach number about 0.15 above that for the unswept cylinder. Comparison of the results for the outermost orifice of the swept cylinder with the results of the unswept cylinder indicated that the difference in pressures (up to the Mach number at which the pressure decrease occurs) conforms approximately to the simple sweepback theory; that is, the pressures developed are a function of the dynamic pressure and Mach number of the flow normal to the axis of the cylinder. The rapid pressure decrease on the swept cylinder occurred, however, at a considerably lower Mach number than would be expected from application of the simple theory to the unswept-cylinder results.

The static pressures on the sides of the wedge (fig. 4(e)) were practically constant at Mach numbers from 0.7 to about 0.9. At Mach numbers between about 0.9 to 1.17, a large increase in the pressure occurred. The value of the pressure obtained at the highest Mach number tested, 1.17, agreed well with the theory of oblique plane shock waves (reference 5) for a Mach number of 1.20 (the lowest Mach number for which the theory indicates an attached shock wave).

CONCLUSIONS

Measurements at transonic speeds of static pressures at the rear of two unswept circular cylinders of different length-diameter ratio and one sweptback circular cylinder and at the rear and sides of a wedge indicated the following results:

1. The static pressures at the rear of the unswept cylinders and the wedge decreased on the order of 25 to 40 percent of the free-stream pressure with increase in Mach number from 0.70 to 1.0, and then remained nearly constant up to the highest Mach number attained, (1.14 to 1.2).

2. An adverse effect of increasing the length-diameter ratio (or aspect ratio) of the unswept cylinders was noted in that the rapid decrease in the static pressure for the longer cylinder occurred at a Mach number about 0.025 lower than for the shorter cylinder and the pressures at Mach numbers above 1.0 were lower for the longer cylinder.

3. The static pressure at the rear of the 45° sweptback cylinder near the root showed a variation with Mach number generally similar to that for the unswept cylinders; but as the distance from the root increased, the rapid pressure decrease was delayed to increasingly higher Mach numbers.

4. The static pressures at midchord on the sides of the wedge were approximately constant at Mach numbers from 0.70 to about 0.90 and then increased with increasing Mach numbers to a value at a Mach number of 1.17 in close agreement with that calculated by the theory of oblique plane shock waves for a Mach number of 1.20.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCES

1. Gilruth, R. R., and Wetmore, J. W.: Preliminary Tests of Several Airfoil Models in the Transonic Speed Range. NACA ACR No. L5E08, 1945.

2. Stack, John, and Lindsey, W. F.: Characteristics of Low-Aspect-Ratio Wings at Supercritical Mach Numbers. NACA ACR No. L5J16, 1945.

3. Stanton, T. E.: On the Effect of Air Compression on Drag and Pressure Distribution in Cylinders of Infinite Aspect Ratio. R. & M. No. 1210, British A.R.C., 1929.

4. Ferri, Antonio: Influenza del numero di Reynolds ai grandi numeri di Mach. Atti di Guidonia No. 67-68-69, 1942.

5. Taylor, G. I., and Maccoll, J. W.: The Mechanics of Compressible Fluids. Two-Dimensional Flow at Supersonic Speeds. Vol. III of Aerodynamic Theory, div. H, ch. IV, sec. 4, W. F. Durand, ed., Julius Springer (Berlin), 1935, pp. 242-243.

[redacted]

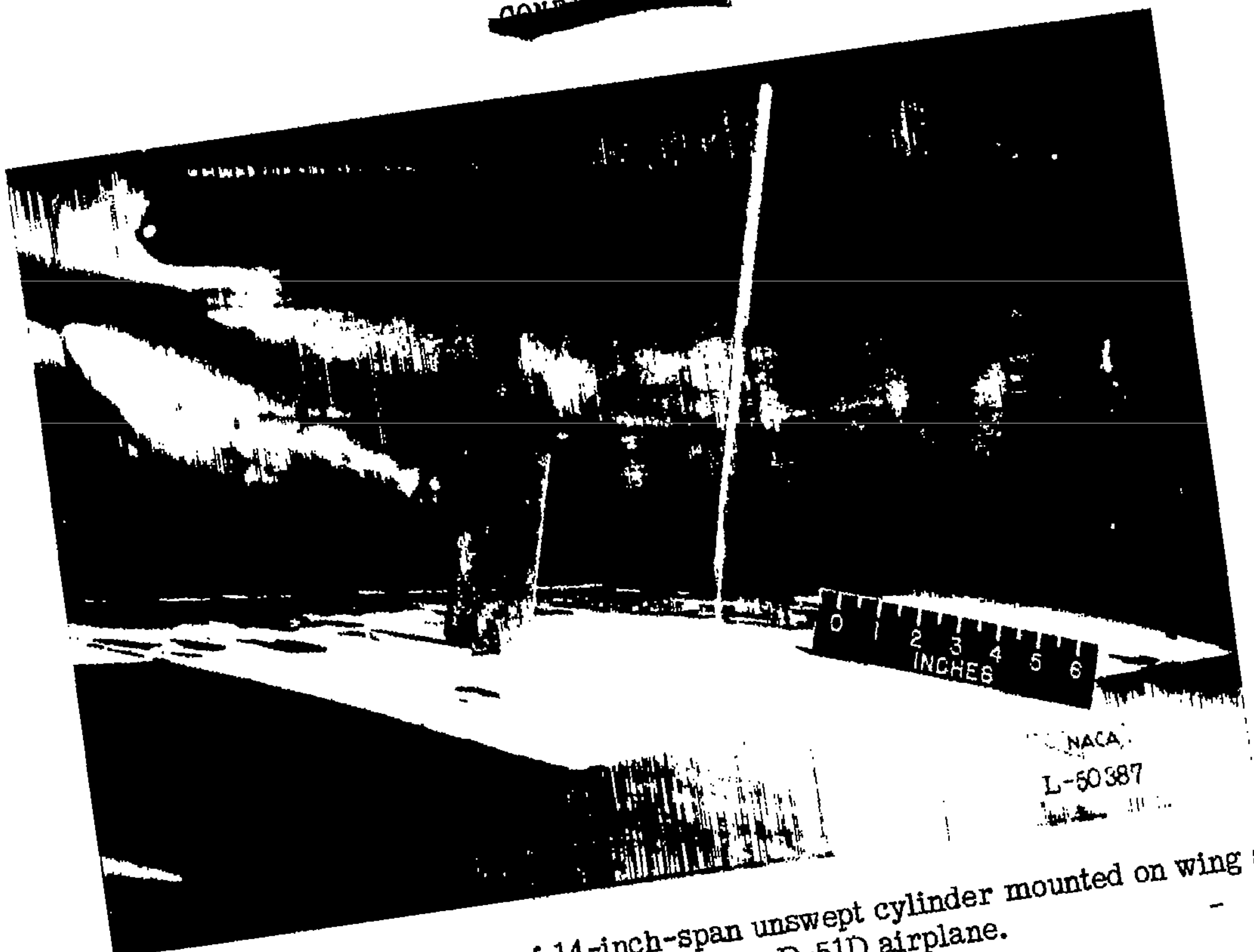


Figure 1.- Three-quarter side view of 14-inch-span unswept cylinder mounted on wing ammunition-compartment door. P-51D airplane.

[redacted]L

~~CONFIDENTIAL~~

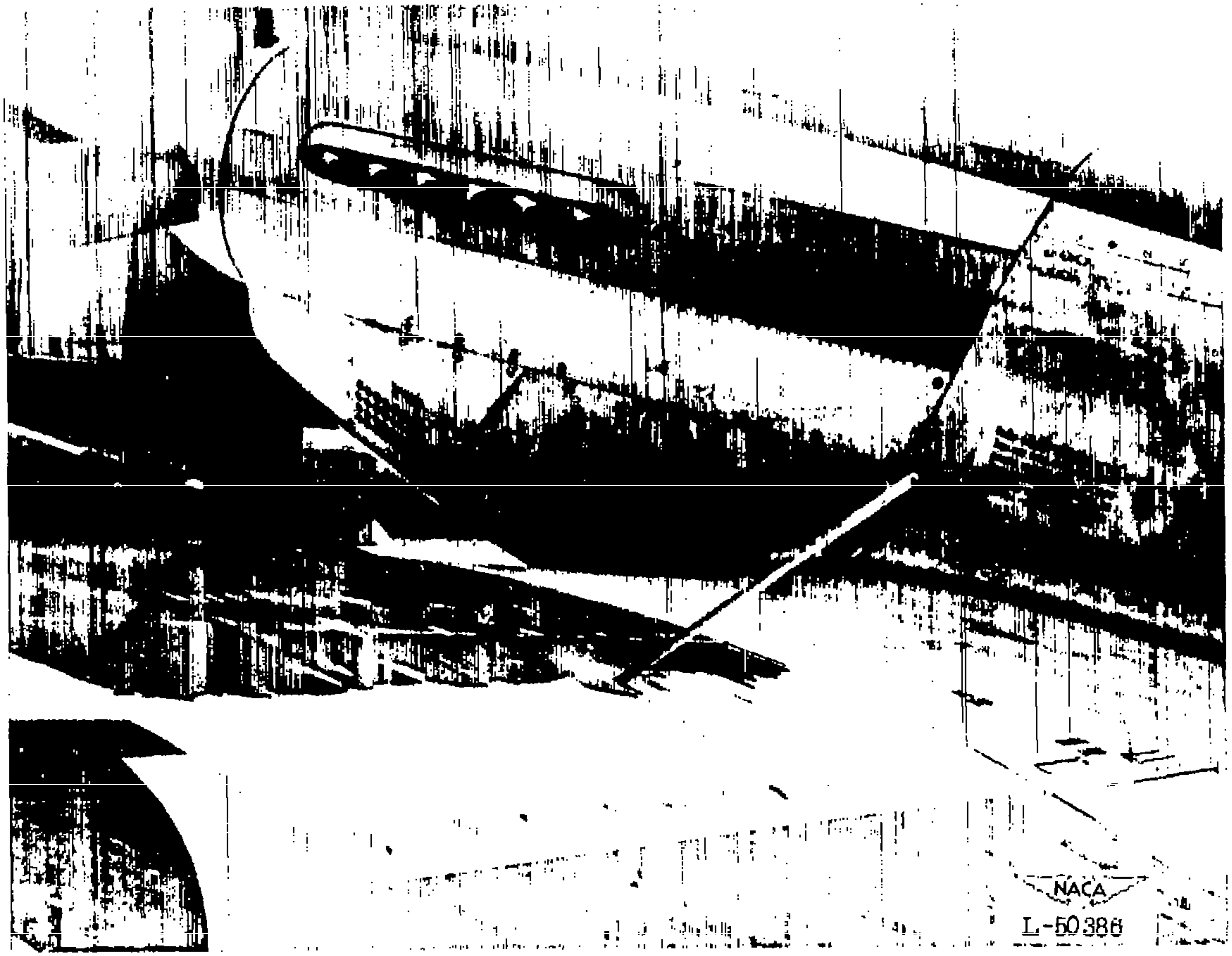


Figure 2.- Three-quarter rear view of 45° sweptback cylinder mounted on wing ammunition-compartment door. P-51D airplane.

[redacted]

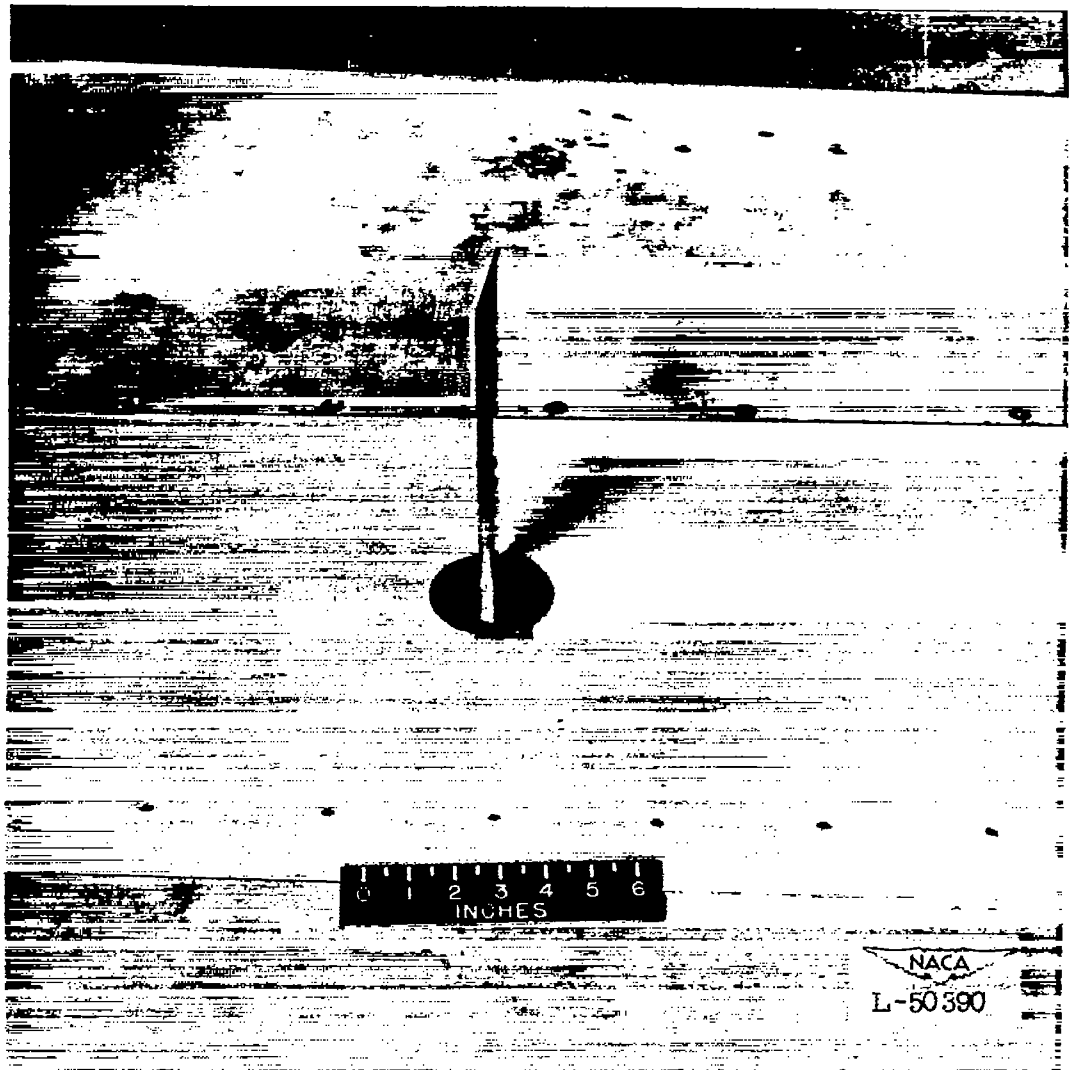
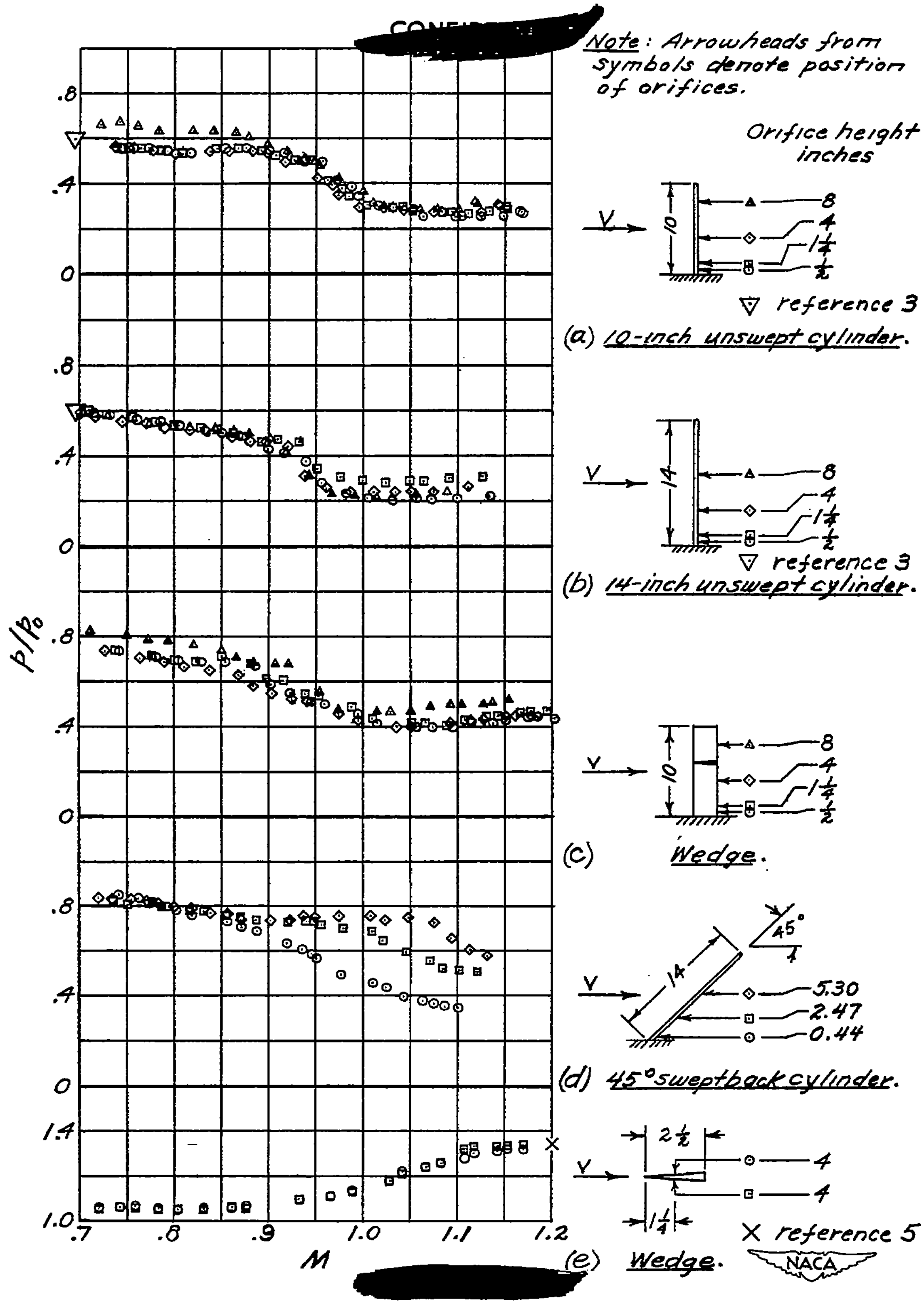


Figure 3.- Rear view of 10-inch-span wedge mounted on wing ammunition-compartment door. P-51D airplane.

[redacted]

[redacted]



[redacted]

Figure 4.- Variation of pressure ratio p/p_0 with Mach number M for the several cylinders and wedge tested.